



US Army Research Laboratory



Weapons and Materials Research Directorate

Multifunctional Protective Coatings for Land Vehicles

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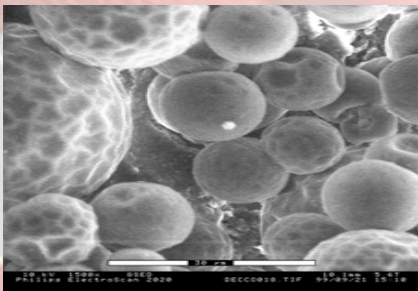
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Courtesy of U.S. DoD



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Courtesy of U.S. Army

- **Who we are & What we do.....**
- **Coatings Systems for Land Vehicles**
 - **Current and future**
 - **Low Solar Absorbing Coatings**
 - **UV Cure**
 - **Near Zero or Zero VOC**
- **GAPS to address and Considerations for Coatings Advancement**

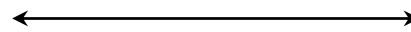


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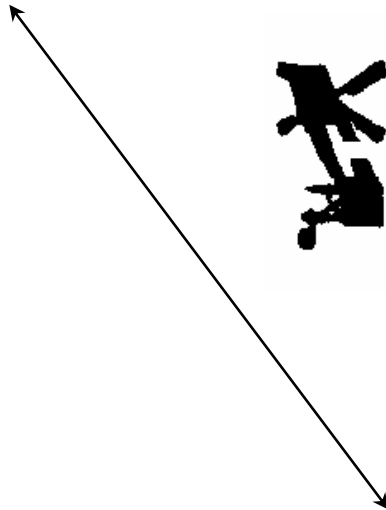


- **ARL is the Lead DOD R&D Activity for CARC**
 - Innovative formulations approaches
 - New raw materials selections
 - Advanced characterization
- **Maintains Ownership for all key specifications regarding pretreatments, primers and topcoats for all tactical and related support equipment and munition coatings.**
- ❖ *Elements above assist to implement and transition products*

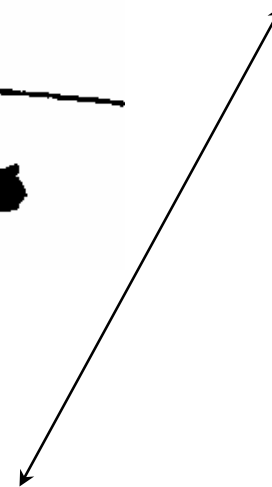
Environmental



Survivability



Durability





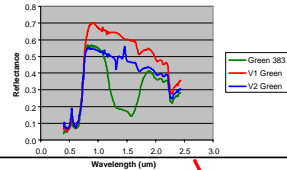
What we do...



- Develop materials for military unique coatings including pretreatments, primers, and topcoats
 - Chemical Agent Resistant Coatings
 - Munitions coatings
 - Industrial coatings for vehicle interiors
- Produce materials and coatings that balance three critical requirements
 - Survivability (camouflage, chemical agent resistance)
 - Durability (appearance, corrosion, compatibility, etc.)
 - Environmental (compliance and pollution prevention)
- Implement and transition new products
 - Specifications and Standards
 - Troubleshooting, consulting, and problem solving
- Analyze and solve technical problems related to coatings systems used on Army Materiel

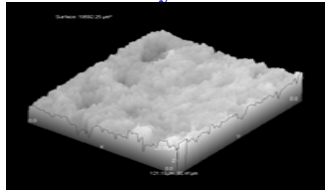
Reflectance

- Specular (gloss)
- Spectral (color)
- IR Spectra



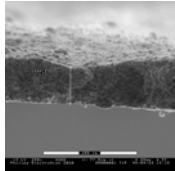
Microscopy

- Physical Changes At Surface
- Failure Analysis



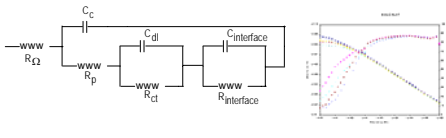
SEM Coating X-section

- Fracture Surface of System
- Constituent Adhesion



EIS

- Equivalent Circuit Models of Corrosion Behavior

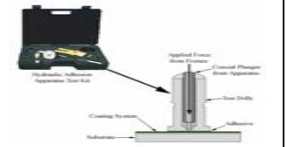


Accelerated Weathering

- Durability, thermal/ irradiated degradation, moisture sensitivity

Adhesion Testing

- Durability, flexibility, strength



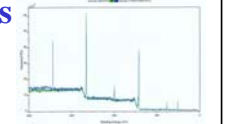
Chemical Structure and Transport Properties

- FTIR/ATR, Raman, GC-MS



SEM-EDX, SAM, XPS, UV-VIS

- Chromium concentrations
- Oxidation states

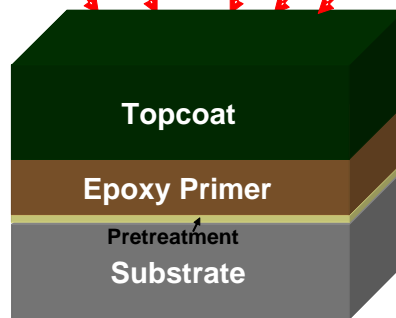


Accelerated Corrosion Testing

- Permeability, corrosion resistance

DMA, DSC

- T_g , stiffness, cross-link density, extent of cure



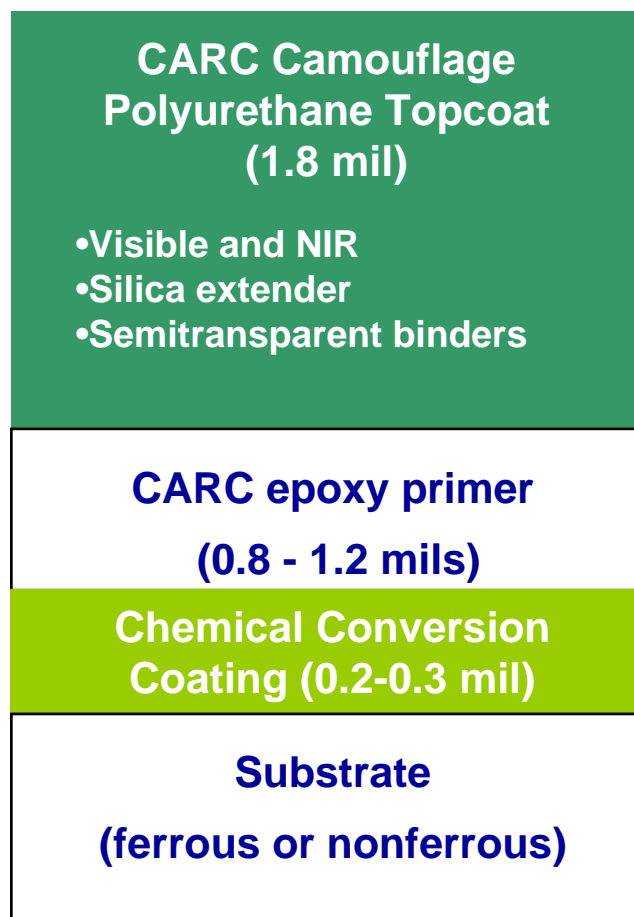


CARC as a System

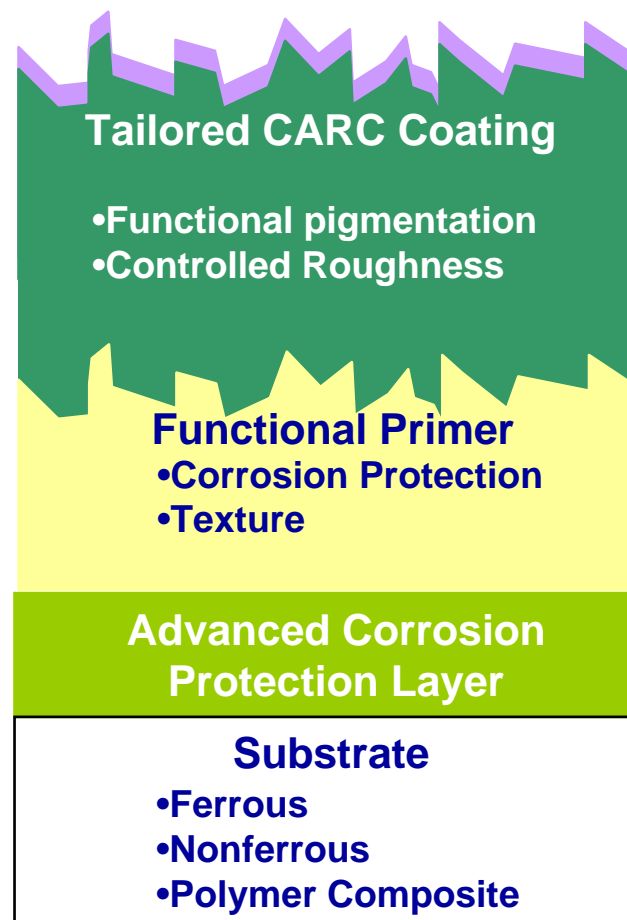


Hierarchical Architecture of Multifunctional Coatings

Today



Tomorrow

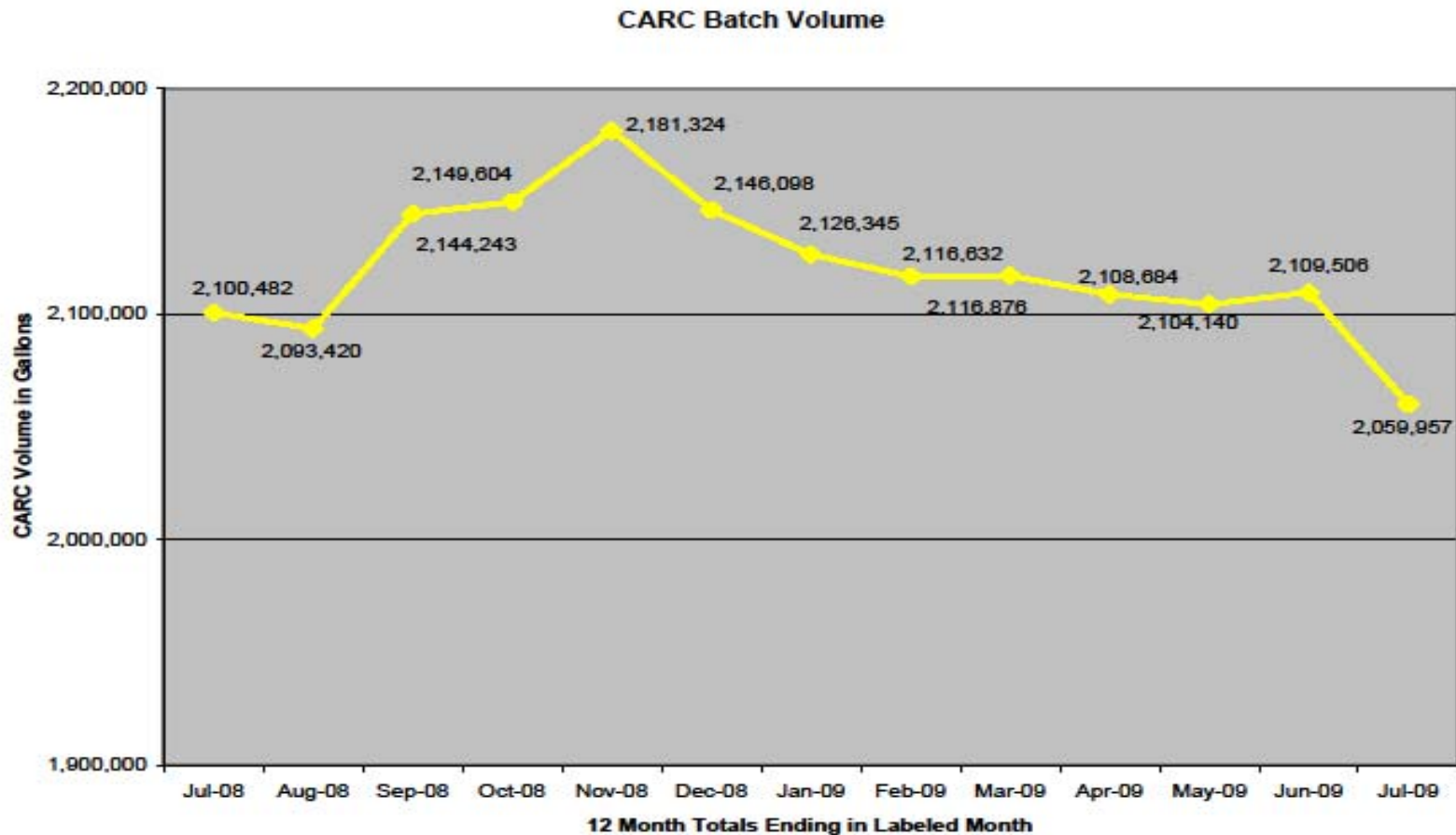




Current Volume of Coatings



- Chemical Agent Resistant Coatings (CARC) is mandated by AR-750-1 for all tactical equipment.
- Every initial submission is fully tested and validated for Qualified Listing.
- Each batch from the initial submission is tested for color, gloss, IR and decontamination resistance. Included in the batch submission is batch volume. Next slide total volumes*
- Volume of coatings usage by Army is enormous: Several million gallons costing several hundred of millions of dollars annually will be reduced as developments are implemented and durability is improved.



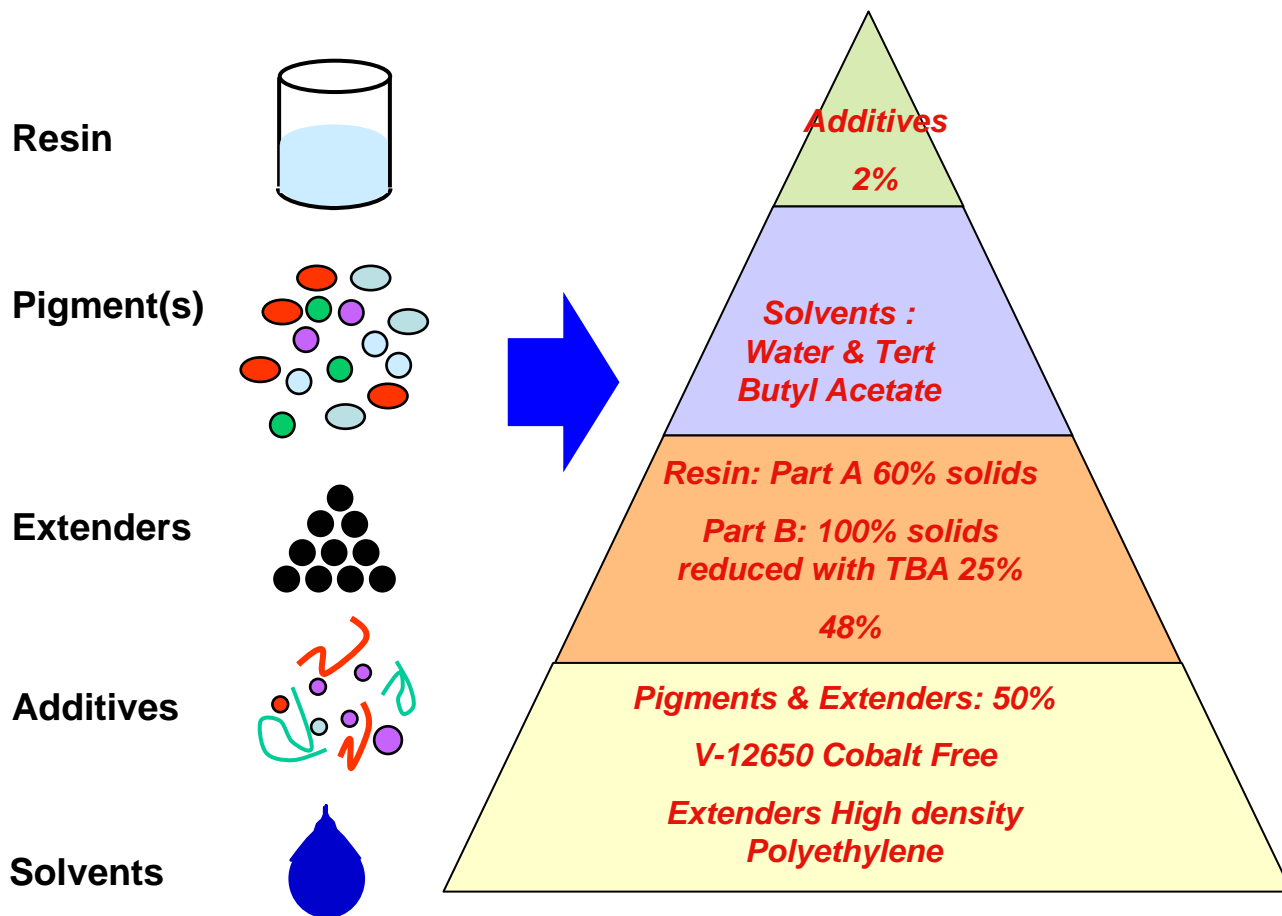


New Paradigm in Coatings

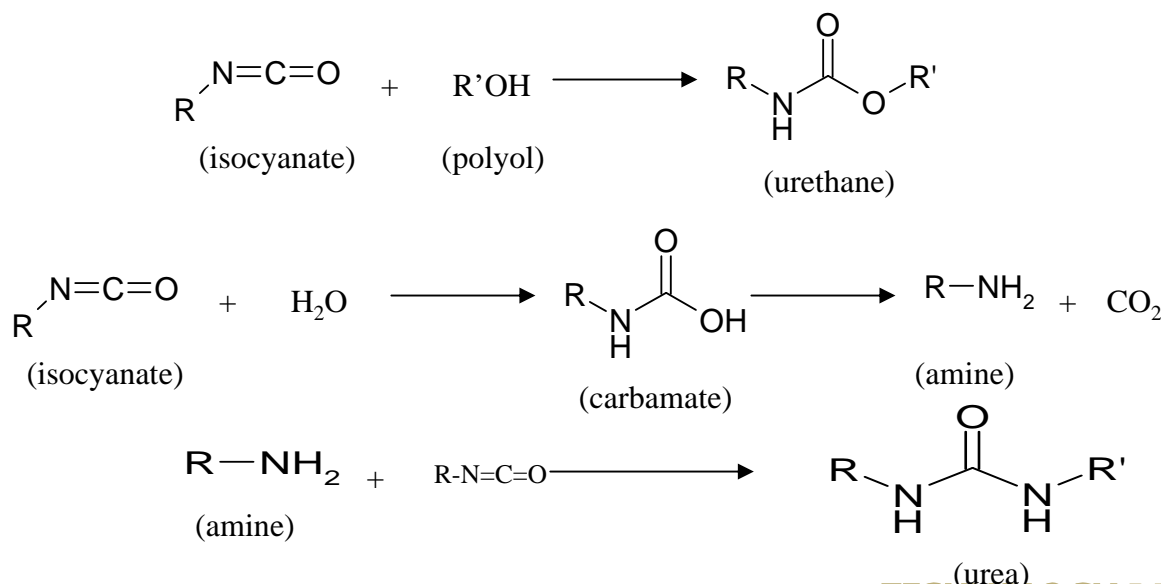


- ❖ Recent Coatings represent superior durability, environmental compliance
- ❖ Stereotypes associated with Emulsions, Water Based or Hexavalent Chromium Free chemistries no longer hold true.
- ❖ Current efforts establishes solid foundation for present and future survivability enhancements and multifunctional capabilities
- ❖ Services are moving rapidly to eliminate standard coatings used and are implementing a new generation of coating technology throughout DOD

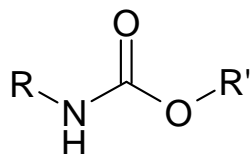
Individual Coating Components



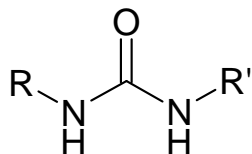
- **New Polyols**
 - Completely water soluble, no cosolvent needed
- **Tert-butyl acetate (VOC exempt) to dissolve and disperse isocyanate**
- **Attempt to reduce NCO:OH indexing to reduce solvent content**



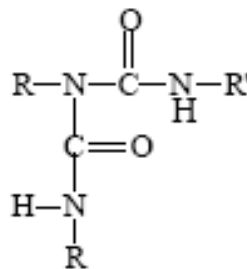
- Unacceptable CAR at $\text{NCO}:\text{OH} < 4$
- Moisture Cure uses blocked Isocyanate chemistry
- 2K Solvent systems typically 1:1.1 Ratio
- Adjust additives, reaction conditions, etc.
 - to make more favorable distribution



Urethane

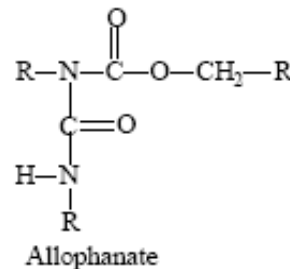


Urea



Biuret

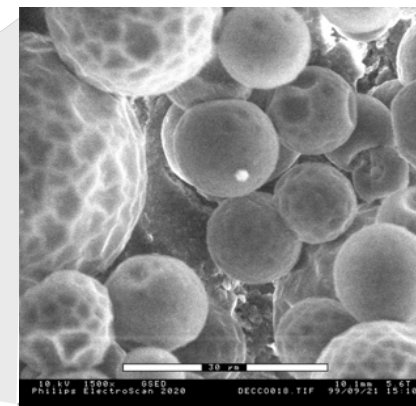
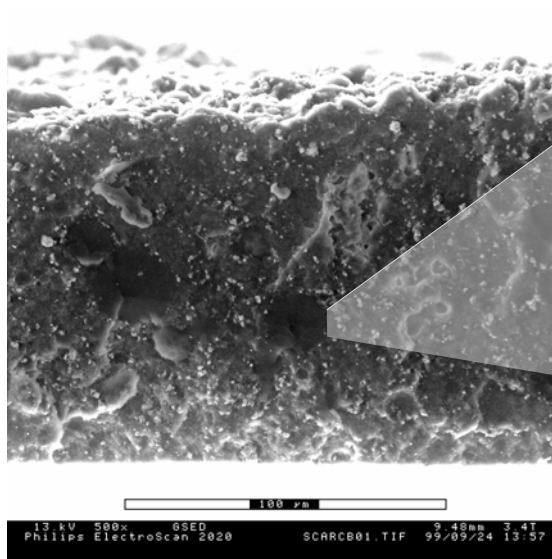
(Urea +
isocyanate)



Allophanate

(Urethane
+
isocyanate)

Polymeric beads



• Integrated within Film

- Polymeric beads
 - Reduce chalking effect
 - Improve UV resistance
 - Improve performance



Diatomaceous silica

Talc

Objective:

Provide advance coatings technology that will increase the functionality and durability of Army materiel



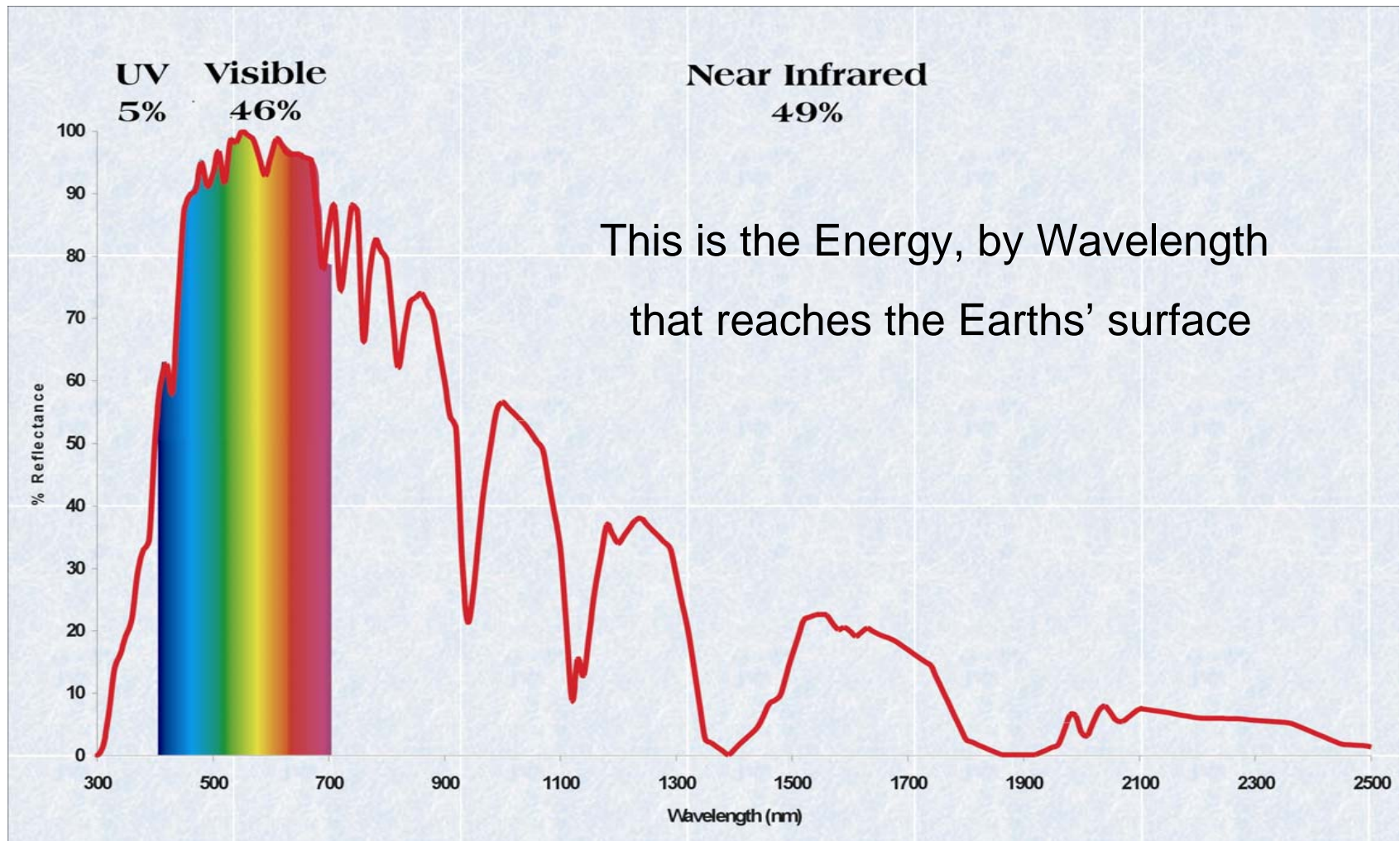


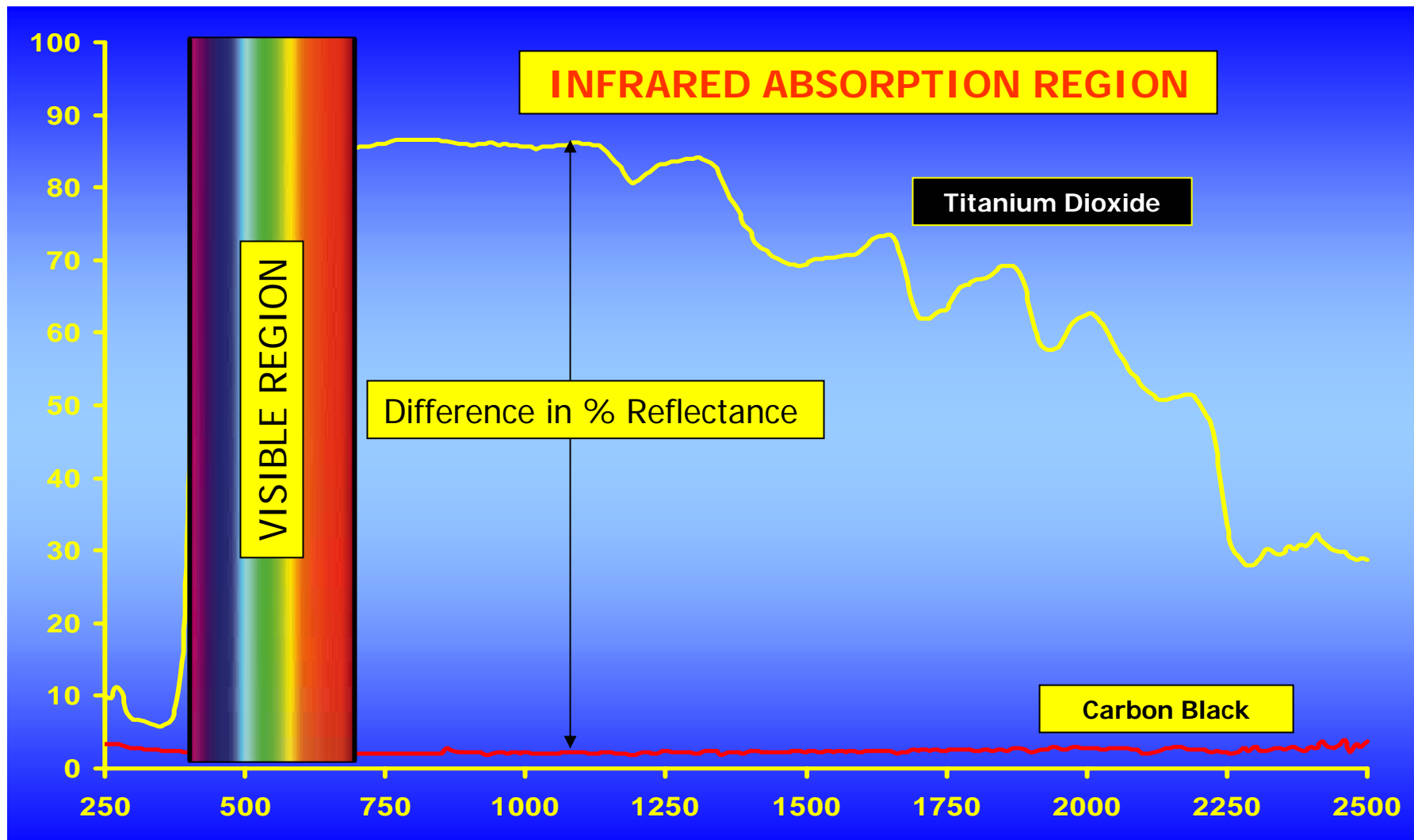
Low Solar Absorbing CARC



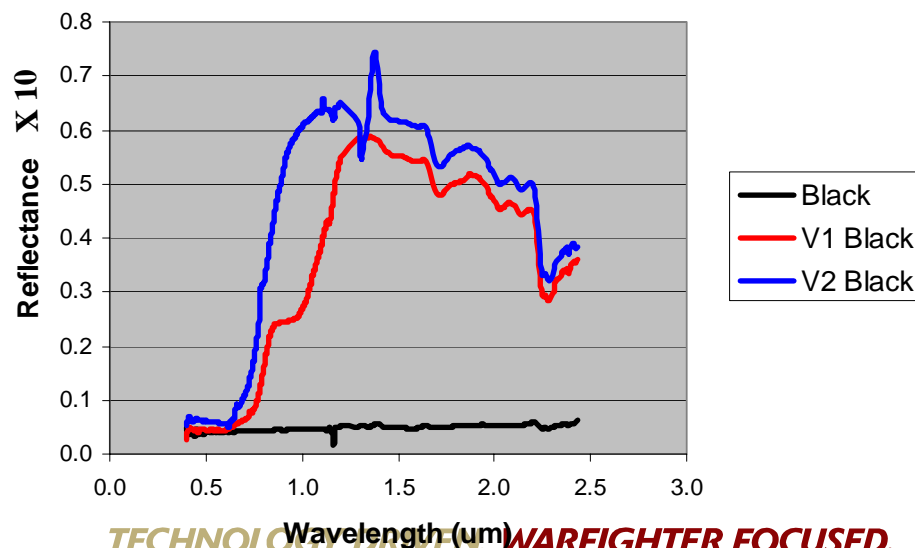
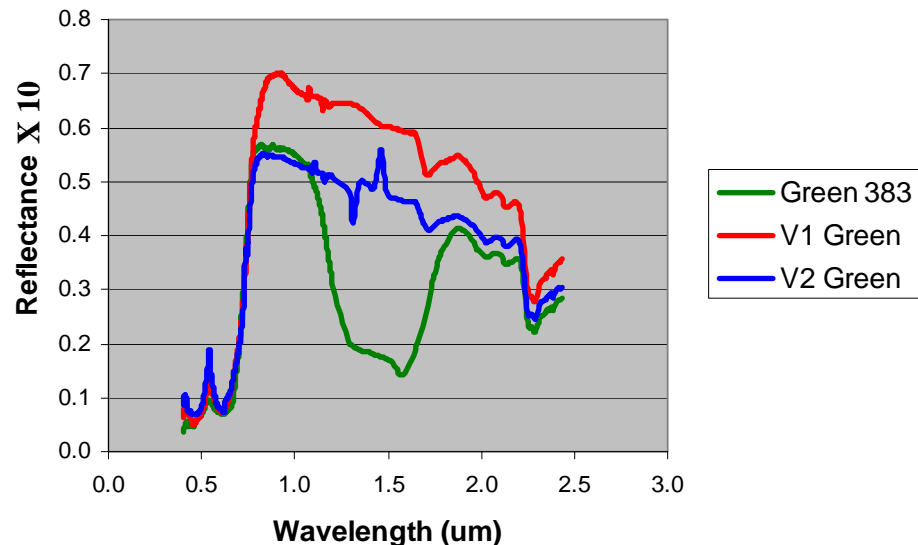
- 8 year weathering excellent: Less than 1.5 color unit change
- Formulated Primary Colors
- IR requirements will shift from 380nm -900nm to 380nm-2000nm with emphasis on 750nm to 1700nm.
- Visible unchanged
- Key highlight: COST, cobalt spinal increase of 300% and availability erratic.
- Formulation will be cobalt free for 383 Green, AC Green, 383 Brown
- Specification is currently being reviewed by vendors and government agencies
- **383 Green to change to 808 Green to identify change**

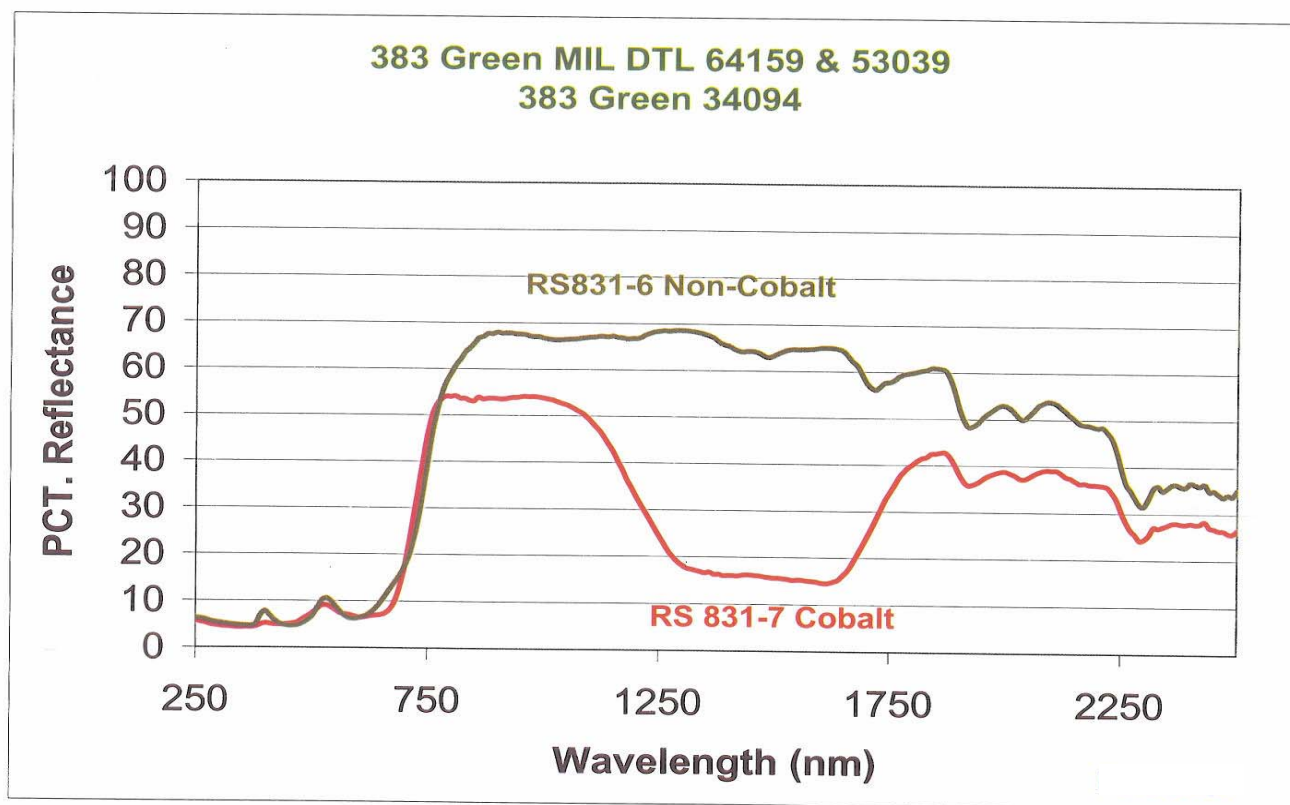
Sun's Energy Primarily in Visible & Infrared Spectrum





- ❖ Visually identical colors
- ❖ Higher Reflectance lower Temperature
- ❖ Reduce current coatings surface temperatures 20 to 50 Fahrenheit
- ❖ Major reductions in sustainability cost with extended coating life and with lower operating temperatures







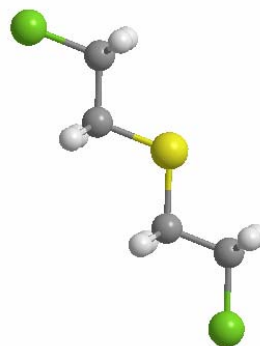
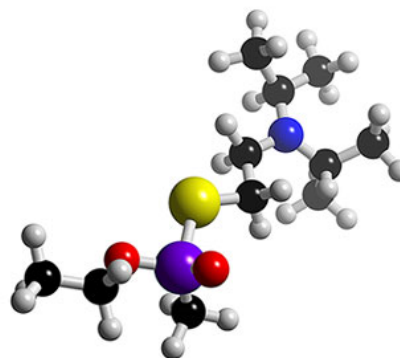
UV Cure Topcoats



- ARL formulated hybrid of UV initiated and Cross linked system
- Reduce Dry through cure to 15 minutes
- Excellent MEK resistance 17hrs
- Can create current color palate
- Industrial low cost lamps as only additional capital cost
- Will include as new type in our topcoat specifications
- Move toward Primers for rapid field repair and touchup



Self-Decontaminating Coatings : DTRA



First Generation Coatings



MIL-DTL-53039



- New types to include 1.0, .5 and zero VOC (Lbs/gal) with zero HAPs flattened with non-silica based raw materials.
- Inclusion of 34201 color (Woodland Desert Sage) Currently used on CH-47 and Foilage Green 504 (used on Helmets).
- Elimination of reference to MIL-T-81772 Aircraft Thinner (100% VOCs)
- Allowing vendors to provide exempt solvent package and provide a universal exempt solvent



MIL-DTL-53030 Water Based Epoxy & MIL-DTL- 53022 Solvent Based



- New type to include Enhanced Corrosion Resistance and require cyclic corrosion evaluation.
- 700Hrs Neutral Salt Fog
 - ASTM D610 RATING OF 9
 - ASTM D1654 RATING OF NOT LESS THAN 6 FOR STEEL
 - ASTM D1654 RATING OF NOT LESS THAN 8 FOR AL.
- 40 Cycles
 - ASTM D1654 RATING OF NOT LESS THAN 7 FOR STEEL & AL.
- Open to novel corrosion inhibitors
- Allowing vendors to provide exempt solvent package and provide a universal exempt solvent
- Similar effort to occur for 53022



MIL-DTL-53084 E-Coat

MIL-PRF- XXXXX Powder Coat



- MIL-DTL-53084 and Powder to include the color Black.
- Open to novel corrosion inhibitors
- Powder Specification to include both Primer and Topcoat within same document
- Coordination Date 12/09



Cr6+ Free Pretreatment for Wash Primer DoD Applications



Multi-Substrates:

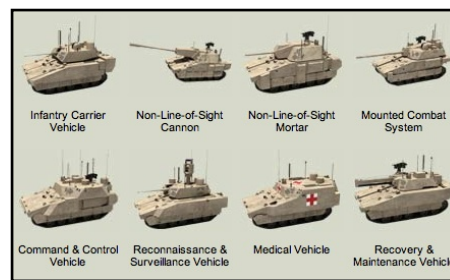
- Steel 1010, 1008
 - Galvanized steel
 - Stainless steel
 - Al 2000/5000/6000/7000 series
 - Ceramic/Composite
-
- **Coating:** must be compatible with existing military topcoats and primers
 - Three vendors have responded with products
 - SERDP effort with PPG & ARL for Zinc Phosphate Alternative
-
- **Process:** Depot and Repair

Aluminum Alloy 5059 For Armor Applications Foreign Comparative Test Program

- Updated military Al armor specification MIL-DTL-46027K
- Over \$14M to date in acquisition
 - \$12M+ in direct procurement of AA5059 for RG-33 MRAP
 - Over \$1.1M of acquisition by OEMs for internal testing, design, and prototyping
 - AA5059-H131 chosen as primary (100%) common hull material for all 8 variants of the PM FCS-BCT Manned Ground Vehicle (MGV) by Boeing (LSI), General Dynamics, and BAE Systems



MRAP RG-33



(8) MGV Mission Based Variants



- Related work - military specification MIL-DTL-32262 created for 6061 Al

- Current operations and future mission requirements have led to recent reassessments on AI for armor
 - AA5059-H131 (now in MIL-DTL-46027K)
 - AA2139-T8 (Under review for MIL SPEC addition)
 - Additional alloys & tempers
- Interest from U.S. Army and the USMC AA2139-T8 due to significantly improved mechanical properties and ballistics.



- The key hurdle is acquiring long term outdoor exposure data for platforms making current and near future decisions.
- Confidence that our accelerated screening processes are relevant to long term exposure results.
- Ensuring pretreatment and coating processes are followed accurately to enhance corrosion resistance and provide adequate adhesion/compatibility for subsequent coatings.



Multiple Step Approach



- **Phase I: Manufacturer data, claims and performance parameters (acceptance based on environmental compliance, cost to include return on investment and process requirements)**
- **Phase II: ARL/TARDEC testing and evaluation of pretreatment or process using coupon panels to include accelerated and cyclic corrosion, EIS, and related adhesion type evaluations etc.**
- **Phase III: Application of component parts**
- **Phase IV: Outdoor exposure in corrosive environment of component parts (Items would be monitored for x years at 6 month intervals)**
- **This Phase type process would allow PMs to be aware of what items are currently being evaluated and also providing a certain level of confidence to select or use a particular new process. Baselines will be selected and used as standards for comparison. In this way new technologies can be evaluated and data acquired.**

- **Establish Baseline Coating System.**
- **Request other Services also establish Baseline Coating Systems.**
- **Assurance of film thickness and cure history.**
- **This would provide an opportunity to accurately compare data and perhaps support claims of “ Better or Enhanced”**

Increased Options for Balanced Requirements

